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GEOLOGY, ENERGY, AND MINERAL (GEM) RESOURCE ASSESSMENT OF THE GARDNER MOUNTAIN GEM RESOURCE AREA (GRA), WYOMING, INCLUDING THE GARDNER MOUNTAIN WILDERNESS STUDY AREA (WY-060-201), AND THE NORTH FORK POWDER RIVER WILDERNESS STUDY AREA (WY-060-202)

PHASE I

Contract No. YA-553-CT2-1055

Prepared for:

U.S. Bureau of Land Management

Prepared by:

Tetra Tech, Inc.
Pasadena, California

August 1983

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EXECUTIVE SUMMARY

The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data concerning Wilderness Study Areas (WSAs). To facilitate this review, certain WSAs with similar geologic environments and mineral characteristics have been grouped together into larger GEM Resource Areas (GRA). Using these guidelines, the Gardner Mountain and North Fork Powder River WSAs were grouped together into the larger Gardner Mountain GRA. This report, which terminates the Phase I activities for the Gardner Mountain GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the WSAs.

The Gardner Mountain GRA contains two WSAs: the Gardner Mountain WSA (WY-060-201), and the North Fork Powder River WSA (WY-060-202). Both WSAs are located within BLM's Buffalo Resource Area, Casper District, Wyoming.

The potential occurrence of GEM resources within the Gardner Mountain and North Fork Powder River WSAs (WSA) is considered low to moderate. Both WSAs are considered to have a moderate favorability based on direct, but quantitatively minimal, evidence for the occurrence of uranium (classified 3C). Uranium may occur as sedimentary types of deposits in Paleozoic and Mesozoic Sandstones within paleokarst terrain at the top of the Madison Limestone, and in fractured deposit types associated with anticlines and other structural features underlying the WSAs (Damp and Brown, 1982). Both WSAs are considered to have a low favorability based on indirect evidence for the presence of metallic minerals (classified 2C). Both WSAs are considered to have a low favorability for the potential occurrence of oil, gas, and geothermal resources (classified 2C): this classification is based on direct, but quantitatively minimal evidence. The Gardner Mountain WSA has a moderate favorability for the potential occurrence of limestone (classified 3C); this classification is based on direct but quantitatively minimal evidence. Quantitatively minimal direct evidence exists to support a low favorability classification for the potential occurrence of all other GEM

resources (classified 2C). This classification is based in part on the geologic environment and inferred geologic processes that have been identified within the WSAs.

Additional geologic investigations would help supplement the GEM resource evaluation of the Gardner Mountain GRA. Additional geologic mapping of the area is strongly recommended because of the lack of suitable large scale geologic mapping within the area. This mapping is critical to define favorable geologic units and provide valuable information to assist in making wilderness decisions. A moderate amount of geological information is available which should be reviewed by BLM personnel to gain additional insight into the potential occurrence of GEM resources within the WSAs prior to making wilderness decisions.

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GEM RESOURCE AREA

GARDNER MOUNTAIN

1.0 INTRODUCTION

1.1 Purpose of Study

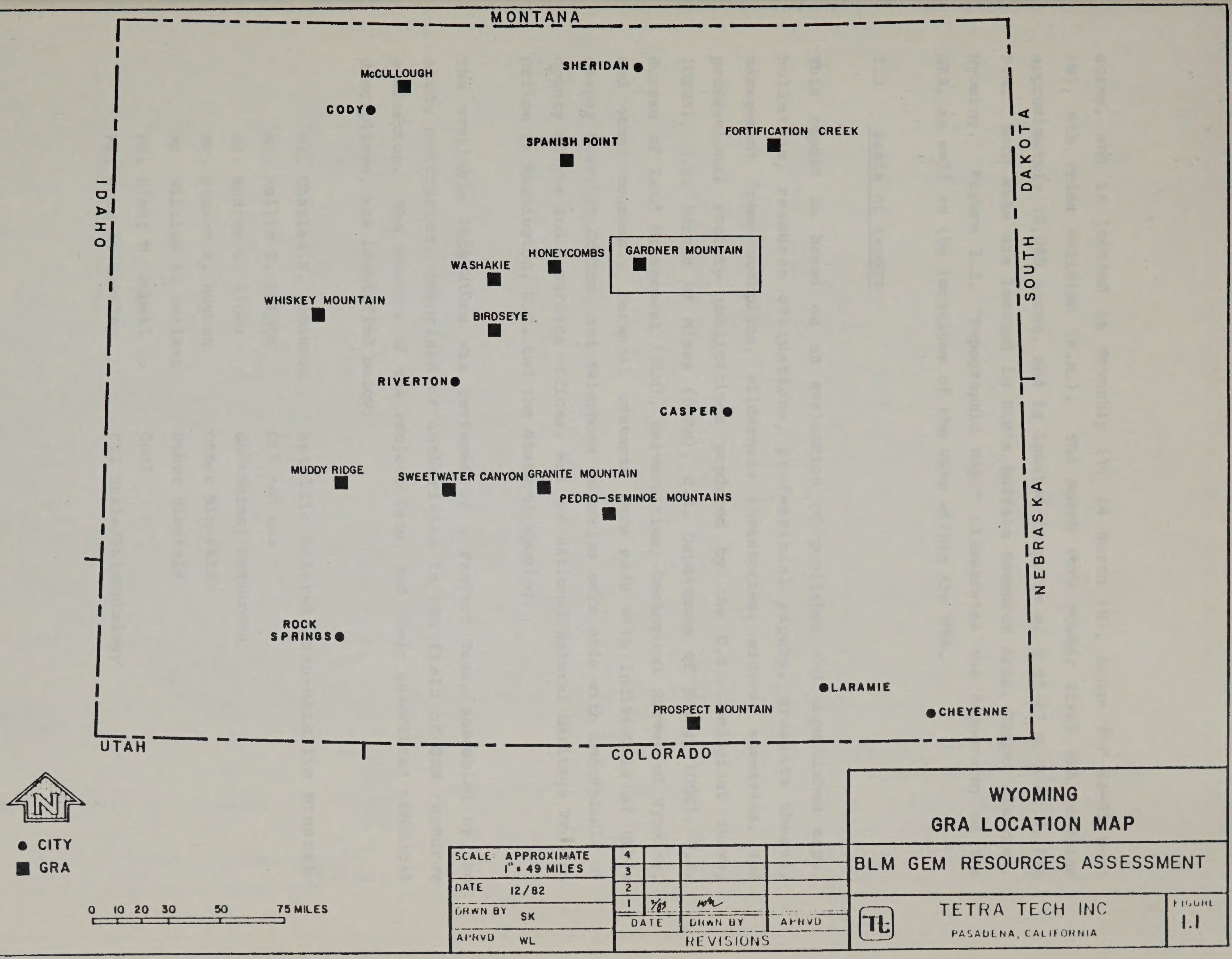
The U.S. Bureau of Land Management (BLM) has adopted a two-phase procedure for the integration of geologic, energy, and mineral (GEM) resources data for suitable/nonsuitable decisions concerning Wilderness Study Areas (WSAs). Phase I consists of a review and evaluation of existing data, resulting in an interpretation of the GEM resource potential of the WSAs. Phase II is designed to generate only the additional data required to support the GEM resource recommendations presented during Phase I. To facilitate this review, certain WSAs with similar geologic and mineral characteristics have been grouped together into larger GEM Resource Areas (GRA). Using these guidelines, the Gardner Mountain and North Fork Powder River WSAs were grouped together into the larger Gardner Mountain GRA. This report, which terminates the Phase I activities for the Gardner Mountain GRA, is an evaluation and interpretation of existing data concerning the GEM resource potential in the Gardner Mountain and North Fork Powder River WSAs.

The GEM resource evaluations for this study were performed by Tetra Tech, Inc. for the U.S. Bureau of Land Management, under Solicitation No. YA-553-CT2-1055. This study was completed in August, 1983.

1.2 Location and Access

This GEM report covers the area identified as the Gardner Mountain GEM Resource Area (GRA); the geographic location of the study area is shown in Figure 1.1, "GRA Location Map."

The Gardner Mountain GRA is located between 106° 40' - 107° 20' west longitude, and 43° 40' - 44° 10' north latitude. The Gardner Mountain GRA contains two WSAs: the Gardner Mountain WSA (WY-060-201), and the North Fork Powder River WSA (WY-060-202). The Gardner Mountain WSA contains approximately 6,423



WYOMING
GRA LOCATION MAP

BLM GEM RESOURCES ASSESSMENT

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PASADENA, CALIFORNIA

FIGURE 1.1

acres, and is located in Township (T) 44 North (N), Range (R) 84-85 West (W), 6th Prime Meridian (P.M.). The North Fork Powder River WSA contains approximately 10,089 acres, and is located in parts of T 45-47 N, R 84 W, 6th P.M. Both WSAs are located in BLM's Buffalo Resource Area, Casper District, Wyoming. Figure 1.2, "Topographic Map," illustrates the topography of the GRA, as well as the locations of the WSAs within the GRA.

1.3 Basis of Report

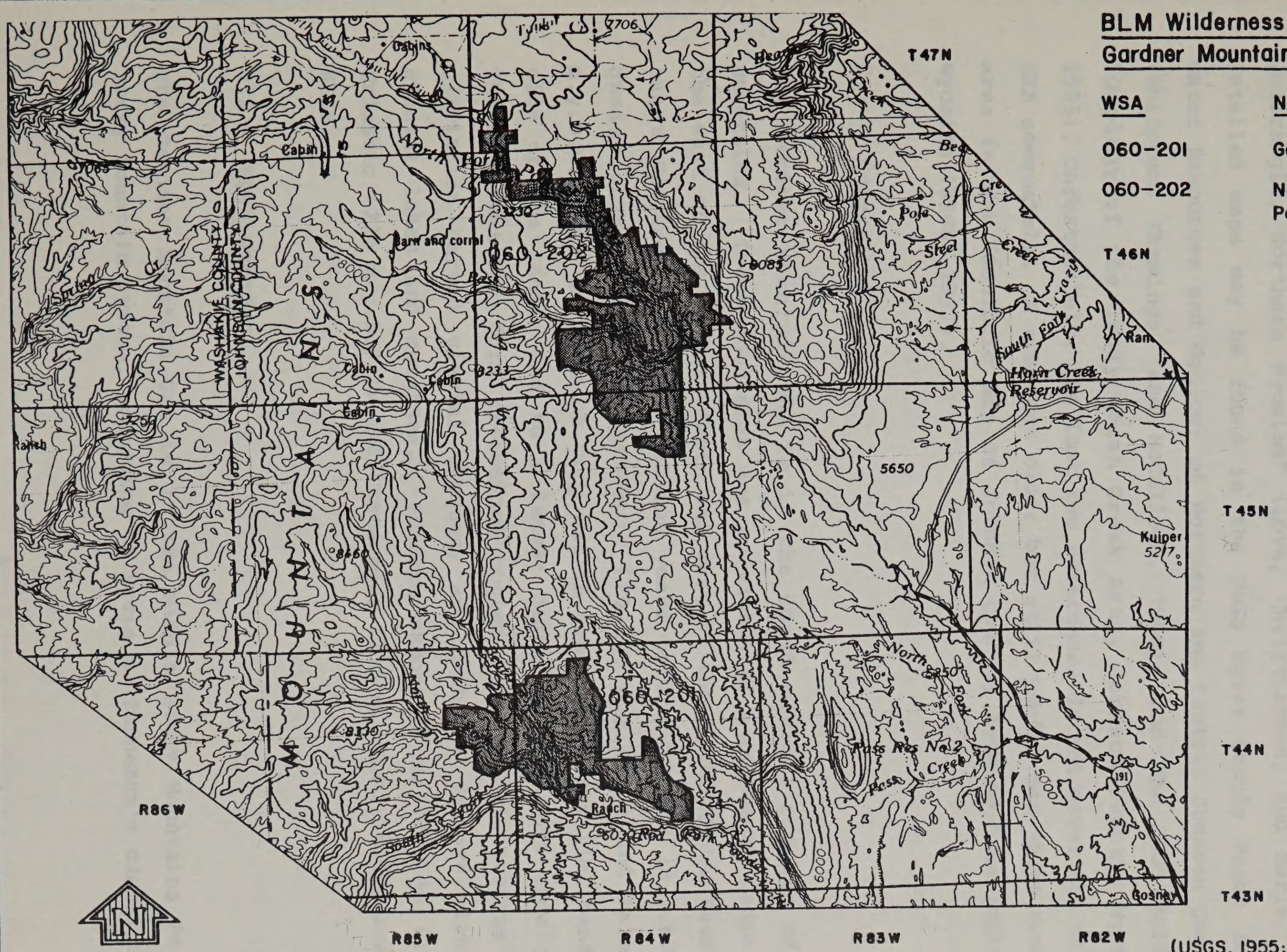
This report is based on an evaluation of published and unpublished maps, bulletins, resource evaluations, professional papers, graduate theses, management frame workplans, wilderness inventories, mineral summaries, and professional society publications produced by the U.S. Geological Survey (USGS), U.S. Bureau of Mines (USBM), U.S. Department of Energy (DOE), U.S. Bureau of Land Management (BLM), universities, Geological Survey of Wyoming, and other sources. Personal contacts were made with individuals of BLM's Casper District Office, and telephone inquiries were made with individuals of county clerks and recorders offices, and the National Natural Heritage Program Office in Washington, D.C. and the State of Wyoming.

The available literature was reviewed by a Project Team, assembled by the study contractor, comprised of authorities in the field of GEM resource evaluation. The members of the Project Team, and their associated technical disciplines, are identified below:

Mr. Charles S. Robinson	Metallic Minerals/Non-Metallic Minerals
Mr. Rollin E. Phipps	Oil and Gas
Mr. Andrew G. Alpha	Geothermal Resources
Mr. Stuart P. Hughes	Other Minerals
Mr. William A. Gallant	Other Minerals
Mr. Elmer M. Schell	Coal
Mr. John A. Hartley	Oil Shale/Paleontology

BLM Wilderness Study Areas Included in the Gardner Mountain GRA

WSA	NAME	ACREAGE
060-201	Gardner Mountain	6,423
060-202	North Fork Powder River	10,089



(USGS, 1955; revised 1974)

NOTE: Contours in 200 ft. intervals.

▨ Approximate Boundary of Wilderness Study Area

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometers

Gardner Mountain GRA, Wyoming

TOPOGRAPHIC MAP

SCALE: 1" = 4 MILES
1 : 250,000

DATE 12/82

DRWN BY SK

APRVD WL

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FIGURE 1.2

2.0 GEOLOGY

The geology of the Gardner Mountain GRA is shown on the north central portion of the "Preliminary Geologic Map of the Arminto 1° x 2° Quadrangle, Central Wyoming" (Love, Christiansen, Earle, and Jones, 1978); and on the south central portion of the "Preliminary Geologic Map of the Sheridan 1° x 2° Quadrangle, Northern Wyoming" (Love, Christiansen, and Earle, 1978). More detailed maps may be found in the USGS Water Supply Paper 1806, "Ground-water Resources and Geology of Northern and Central Johnson County, Wyoming" (Whitcomb, Cummings, and McCullogh, 1966); and the USGS Bulletin 1027-B, "Geology of the Crazy Woman Creek Area, Johnson County, Wyoming" (Hose, 1955). Unfortunately, the last two references do not cover the WSAs within the GRA adequately. A somewhat older but still useful map which covers the whole area is the "Geologic Map of Johnson County, Wyoming," Geological Survey of Wyoming (USGS, 1937).

2.1 General

The Gardner Mountain GRA is in the south central portion of the Bighorn Mountains. These mountains are an elongated north-south range which lie to the east of the Bighorn Basin and west of the Powder River Basin. The range has a Precambrian (> 600 million years before present [m.y.B.P.]) granite-gneiss core overlain by Mesozoic (70-225 m.y.B.P.) and Paleozoic (> 225 m.y.B.P.) rock units which crop out in essentially parallel bands on the east side of the range, and to a lesser degree on the west side of the range. These formations form pronounced hogback ridges, Pleistocene (1 m.y.B.P.) glaciation carved glacial cirques, and u-shaped valleys with accompanying glacial lakes and moraines. Surface exposures of Permian (270 m.y.B.P.), Triassic (225 m.y.B.P.), and Cretaceous (135 m.y.B.P.) rocks are found in the WSAs.

2.2 Physiography

The Gardner Mountain GRA is in the Middle Rocky Mountains Province of the Rocky Mountain system, according to Nevin M. Fenneman's classification of the

physical divisions of the United States (Fenneman, 1931). The GRA ranges in altitude from 5,000 to 8,500 feet, with a relief of 3,500 feet. The lowest section of the GRA is in the southeast portion and the highest section is in the north central portion of the GRA. There are the remnants of an old erosion surface at approximately 8,000 feet within the GRA, leaving a relatively flat surface or peneplane that has been eroded by streams in recent geologic time.

The North Fork Powder River WSA ranges in altitude between 5,900 to 8,000 feet, with a relief of 2,100 feet. The Gardner Mountain WSA is at a generally lower altitude than the North Fork Powder River WSA; within the Gardner Mountain WSA, altitudes range between 5,700 feet to 7,700 feet.

The Gardner Mountain GRA has an average annual precipitation of approximately 15 inches, and an annual temperature mean of 44°F. The study area has a low monthly average temperature of approximately 19°F in January, and a maximum monthly average temperature of approximately 70°F in July.

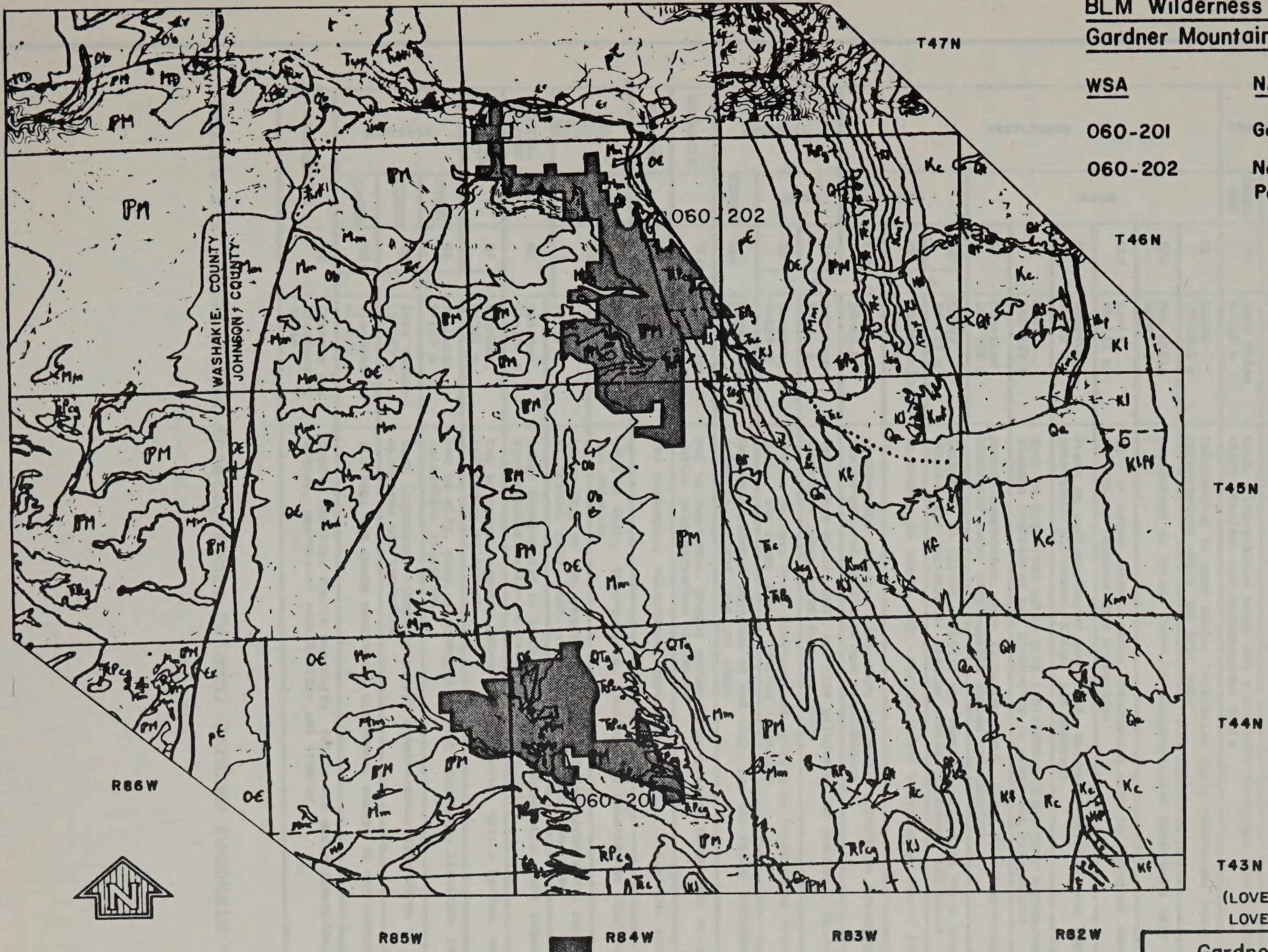
2.3 Geologic Units

The Gardner Mountain GRA has a relatively complete stratigraphic section that ranges from Precambrian igneous and metamorphic rocks through sedimentary rocks of Tertiary (2-70 m.y.B.P.) age.

There are several anticlines in the study area. In general, these anticlines have steeper limbs on the west side of the Bighorn Mountains. The most common types of faulting that occur within the GRA are reverse faults. Surficial deposits consist of Quaternary clay, sand, and gravel in the stream bottoms and some terrace gravels. Figure 2.1, "Geologic Map," delineates the geologic formations that occur throughout the GRA. Figure 2.2, "Generalized Stratigraphic Column," is a generalized stratigraphic column which provides a brief description of all the stratigraphic units that underlie the Gardner Mountain GRA.

BLM Wilderness Study Areas Included in the Gardner Mountain GRA

WSA	NAME	ACREAGE
060-201	Gardner Mountain	6,423
060-202	North Fork Powder River	10,089



(LOVE, CHRISTIANSEN, and EARLE, 1978; LOVE, CHRISTIANSEN, EARLE, and JONES, 1978)

▨ Approximate Boundary of Wilderness Study Area

5 4 3 2 1 0 3 6 Miles

5 4 3 2 1 0 5 10 Kilometer

SCALE: 1" = 4 MILES
1:250,000

DATE: 12/82

DRWN BY: SK

APRVD: WL

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2			
1	3/83	SK	

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Gardner Mountain GRA, Wyoming

GEOLOGIC MAP

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PASADENA, CALIFORNIA

FIGURE 2.1

SYSTEM	SERIES	SYMBOL		FORMATION, THICKNESS, FT	GENERAL LITHOLOGIC DESCRIPTION
QUATERNARY		Qa		Alluvium	
		Qt		Terrace Deposits	
		QTg		Undifferentiated Gravels	
TERTIARY	OLIGOCENE	Twr		White River 0-457 m	Light brown bentonitic claystones, interbedded with conglomerates, cemented by calcium carbonate and light gray tuffaceous marlstone
	PALEOCENE	Tfu		Fort Union 0-762 m	Coal, fine-grained sands and silts with ironstone concretions; interbedded clays, shales, and carbonaceous shale
CRETACEOUS	UPPER	Kl		Lance 198-915 m	Yellow-gray to gray shale; lenticular silty sandstone; interbedded dark-gray, carbonaceous shale and coal beds
		Kfh		Fox Hills 30-91 m	Light-gray to white, fine- to medium-grained sandstone; gray shales
		Kls		Lewis 53-122 m	Gray to brown, marine shale interbedded with fine-grained sandstone and siltstone; carbonaceous sandstones
		Kmv		Mesaverde 0-366 m	Fine- to medium-grained sandstone, carbonaceous shale and lignite, gray to gray-brown siltstone, shale, and mudstone
		Kc		Cody 762-823 m	Gray to dark-gray shale with interbedded light-gray bentonite; Sussex and Shannon Sandstones are light-gray to green and glauconitic
		Kf		Frontier 194-250 m	Marine sandstones, gray to yellow-brown, fine- to medium-grained, thin bentonite beds; carbonaceous shales and lignites
	LOWER	Km	Kmt	Mowry 56-149 m	Dark-gray to silver, brittle and fissile, siliceous shale with interbedded cream-white bentonites; shallow marine sandstone; siltstone
		Kt		Thermopolis 30-61 m	Dark-gray to black, soft, marine shale; interbedded shaley siltstone
		Kcl	KJ	Cloverly 18-82 m	Light-gray, slightly calcareous and sandy siltstone; variegated shales; coarse-grained sandstone and conglomerate
JURASSIC	UPPER	Jm		Morrison 51-91 m	Variegated green, red, and gray siltstone and mudstone, fine-grained sandstone lenses with dinosaur bones
		Js		Sundance 0-106 m	Green, yellow, gray, fine-grained sandstones interbedded with siltstone, shale, and limey shale; oolitic limestone
	MIDDLE	Jsg		Gypsum Spring 0-58 m	Marine evaporite sequence of red shale and siltstone; interbedded limestone, dolomite, gypsum, and red shale
TRIASSIC		TRc		Chugwater 183-305 m	Red to red-brown, poorly sorted, fine-grained sandstone; siltstone and shale; thin carbonate sequences
PERMIAN		Pg		Goose Egg 61-107 m	Red sandstone, siltstones, gypsiferous shale, limestones, and evaporites
PENNSYLVANIAN		IPM		Tensleep 37-105 m	Buff to white, fine-grained, cross-bedded sandstones; thin beds of limestone and dolomite
				Amsden 58-76 m	Light-gray to tan, cherty limestone and dolomite; soft, red sandstone and siltstone; gray, buff, erosive, fine-grained sandstone
MISSISSIPPIAN		Mm		Madison 61-244 m	Karst development in fossiliferous limestone with chert lenses; vuggy, fine-grained, thin- to medium-bedded dolomite
ORDOVICIAN		Ov	OЄ	Bighorn 0-229 m	Tan to brown, massive dolomite; gray-brown, thinly bedded, medium-grained sandstone; siltstone
CAMBRIAN	UPPER	Єg		Gallatin 9-123 m	Red to pink, gray, glauconitic, silty limestone; limestone pebble conglomerate; calcareous siltstone
	MIDDLE	Єgv		Gros Ventre 15-107 m	Gray limestone; limestone pebble conglomerate; gray-brown to green, micaceous siltstone and sandstone
	LOWER	Єf		Flathead 61-122 m	Littoral and beach sandstone, siltstone; coarse to conglomeratic at the base
PRECAMBRIAN		pЄ		Igneous and Metamorphic Rocks	Quartz diorite, quartz monzonite, felsic and mafic agmatites, quartzofeldspathic gneiss, associated amphibolite, and granite

Figure 2.2 Generalized Stratigraphic Column, Gardner Mountain GRA

2.3.1 Rock Units

All of the rock units mentioned above crop out in the Gardner Mountain GRA, but not necessarily in the WSAs. The Gardner Mountain WSA has outcrops of the following rock units: Bighorn Dolomite, Madison Limestone, Tensleep Sandstone, Amsden Formation, Chugwater Formation, and Goose Egg Formation. The North Fork Powder River WSA has outcrops of the following rock units: Cambrian rocks, Bighorn Dolomite, Tensleep Sandstone, Amsden Formation, Goose Egg Formation, Chugwater Formation, Cloverly Formation, and Morrison Formation.

The Precambrian rocks within the Gardner Mountain GRA are mainly granites, pegmatites, amphibolites, and schists. No exposures are found in either of the WSAs. These units are buried beneath Paleozoic and Mesozoic rocks in the WSAs.

The Cambrian (500-600 m.y.B.P.) rocks in the study area include the Flathead Formation, the Gros Ventre Formation, and the Gallatin Formation. The Lower Cambrian is represented by the Flathead Formation, a siltstone and sandstone with a basal conglomerate. The sandstone is composed of tan to light-brown and medium to coarse grained quartz pebbles. The Gros Ventre Formation is middle Cambrian and is composed of a medium-to-coarse grained glauconitic sandstone, with a middle layer of grayish green shale, light gray limestone, thin sandstones, and flat-pebble conglomerate. The upper unit is a silty limestone with thin beds of flat-pebble conglomerate. The Upper Cambrian is represented by the Gallatin Formation, which is composed of glauconitic, silty limestone, limestone pebble conglomerate, and calcareous siltstone.

The Ordovician (440-500 m.y.B.P.) rocks in the study area include the Bighorn Dolomite. The Bighorn Dolomite crops out in both of the WSAs. It consists of a basal unit of light gray to brick red, fine-to-coarse grained quartz sandstone. This sandstone is overlain by a tan, dense, massive, dolomite. The uppermost unit is a slabby argillaceous dolomite.

The Mississippian (300-350 m.y.B.P.) rocks in the study area include the Madison Limestone. The Madison Limestone consists of four major alternating units of limey dolomite which range in color from light tan to gray. The lower 3 feet is sandy and locally conglomeratic. There is some karst development with chert lenses. The sequence varies from thin bedded to massive. The Madison Limestone is exposed as small outcrops in the Gardner Mountain WSA.

The Pennsylvanian (270-300 m.y.B.P.) rocks crop out at the surface of large parts of both WSAs. The Pennsylvanian rocks are represented by the Amsden Formation and the Tensleep Sandstone. The Amsden Formation is composed of soft brick-red fine-grained silty sandstone, light-gray dolomite, soft red claystone, and yellow to tan massive dolomite. Overlying the Amsden Formation, the Tensleep Sandstone consists of a light-tan to gray, or grayish and fine-grained massive to crossbedded sandstone, with dolomite in the lower portion.

The Permian (225-270 m.y.B.P.) rocks in the study area are represented by the Goose Egg Formation. The Goose Egg Formation is found in both WSAs and is composed of red sandstones, siltstones, gypsiferous shales, limestones, and evaporites.

The Triassic (180-225 m.y.B.P.) rocks in the study area are represented by the Chugwater Formation. The Chugwater Formation is found in both WSAs. It has a lower unit of soft interbedded reddish-brown siltstone, shale and silty fine-grained sandstone. Overlying this unit may be a slabby dense light-gray dolomitic limestone. The top unit of the Chugwater is a pink massive sandstone.

Jurassic (135-180 m.y.B.P.) rocks occur in the GRA, but do not crop out in either WSA. The Gypsum Spring Formation represents the Middle Jurassic. It is composed of a lower section of limey gypsum with interbedded reddish brown siltstone and shale. The gypsum may have leached out, leaving a thin

section of limestone breccia and reddish-brown siltstone or shale. Overlying this unit is a reddish-brown claystone and alternating zones of light-gray argillaceous limestone and claystone.

Upper Jurassic rocks occur in the GRA, and in the southeastern portion of the North Fork Powder River WSA. The Upper Jurassic rocks are represented by the Sundance and Morrison Formations. The Sundance Formation consists of sandstones and shales. The sandstones are light-gray to light-tan calcareous, and sometimes glauconitic, which weathers brown. The shales are olive-gray, silty and calcareous. The Sundance Formation may occasionally contain oolitic and conglomeratic limestone. Overlying the Sundance Formation is the Morrison Formation, which is found only in the North Fork Powder River WSA. This formation is primarily sandstone in the lower part and claystone in the upper part. The lower portion of the formation contains beds of yellowish-gray siltstone and fine-grained sandstones interbedded with varicolored shales and claystones. The upper part of the formation contains less sandstones and siltstone, and more red, green, and black claystones. The black hue is from carbonaceous material. Freshwater invertebrate fossils and dinosaur bones are common in the Morrison Formation.

The Lower Cretaceous rocks in the GRA are represented by the Cloverly, Thermopolis, and Mowry Formations; however, none of these formations crop out in the WSAs. The Cloverly Formation has a well developed basal sandstone (locally conglomeratic), a middle layer of varicolored claystone, and an upper layer of slabby siltstone and sandstone beds. The Lower Thermopolis Formation is composed of an upper shale, middle silt, and a lower silt and sand. The lower silt can be recognized in outcrop by its distinctive gray-weathering shale, which consistently separates the brown and tan-weathering "rusty beds" below from the brown and tan-weathering middle silty shale above. The middle Thermopolis Shale, called in certain locations the Muddy Sandstone, is a fissle black shale with a large amount of silt. It also contains varying amounts of sandstone and siltstone. The Upper Thermopolis Shale is dark gray and black with a few ironstone beds and a few prominent white bentonite beds.

The Mowry Formation is a soft, grayish black shale with thin beds of bentonite overlain by light gray, brittle laminated siliceous shale with yellowish bentonite beds and a few thin sandstones.

The Middle Cretaceous rocks in the study area are represented by the Frontier, Cody, Mesaverde, and Lance Formations. The Frontier Formation is composed of a bentonitic dark gray shale and siltstone with four bentonite beds. It also contains interlaminated light gray sandstone and a dark gray shale with a few conglomeratic sandstone beds. The Cody Formation is composed of dark gray shale, soft conglomeratic sandstones, and light gray, fine-to-medium grained soft calcareous sandstone. The Mesaverde Formation is composed of fine-to-medium grained sandstones, carbonaceous shale and lignite, gray to gray brown siltstone, and shale and mudstone. The Lance Formation consists of drab brown, thin bedded shaley sandstone with interbeds of dark gray shale. There are also light to yellowish gray soft sandstones. Beds of carbonaceous shale are present throughout the upper half of the unit.

The Tertiary (2-70 m.y.B.P.) system has only limited exposure within the GRA and none at all in the WSAs. The Tertiary system appears on the east side of the GRA as the Fort Union Formation, and on the west side of the GRA as the White River Formation. The Paleocene series is represented by the Fort Union Formation, which consists of many beds of moderate brown ferruginous resistant sandstone ledges, interbedded with siltstone and shale, overlain by light gray siltstone and gray shaley sandstone, many thick zones of carbonaceous shale interbedded with siltstone, and lenticular beds of conglomerate. The Oligocene system is represented by the White River Formation, which consists of light-brown bentonitic claystones, interbedded with conglomerates, cemented by calcium carbonate and light gray tuffaceous marlstone.

Quaternary deposits are found throughout the GRA and to a lesser extent in the WSAs. They are basically landslide debris, terrace gravels, and alluvium.

2.4 Structural Geology

The Gardner Mountain GRA lies where the southern edge of the Bighorn uplift meets the northern end of the Casper Arch. The GRA contains elements of both the Bighorn Mountain and Powder River Basin structural provinces. The WSAs are in the Bighorn Mountain structural province. High angle reverse faults predominate in the area, but some thrust and normal faults are present (Love et al., 1978).

The influence of faulting is most significant just to the northeast of the northeast boundary of the North Fork Powder River WSA, where Precambrian igneous rocks have been moved adjacent to Paleozic rock units by a fault down thrown on the west. Openings created by tectonically induced fractures in the Madison and Tensleep Formations and others may provide depositional controls over mineral deposits. Primary porosity and karst solution features may also provide mineral depositional control (Damp and Brown, 1982).

2.5 Engineering Geology

Some of the formations present in the WSAs contain clay and shale units (i.e. Goose Egg, Chugwater) which pose a distinct problem in road or other types of construction. Rock units which contain shales and bentonite have a potential for landslides. Rockfalls and other landslide debris can be expected in steep walled canyons associated with the Madison Limestone and Bighorn Dolomite outcrop. Erosional problems can be expected in those poorly cemented sandstone formations with little or no clay binder. Steep narrow canyons have a tendency to concentrate heavy rainfall into flash floods.

2.6 Paleontologic Resources

The Morrison Formation within the region is noted for yielding vertebrate fossils. The White River Formation has a high potential for yielding fossil vertebrates. Many of the other formations in the study area also yield invertebrate fossils. No vertebrate fossils have been known to be recovered in the GRA or WSAs. The favorability for vertebrate paleontologic resources within the WSAs is slight.

2.7 Historical Geology

The geologic history of the Gardner Mountain GRA is similar to that of the middle Rocky Mountains. The basement Precambrian rocks consist of metaigneous and metasedimentary rocks. At the end of Precambrian time and throughout the Paleozoic era, there were repeated advances and retreats of a sea. Marine deposits of sandstone, shale, and limestone were formed. At the end of the Paleozoic era, marine, mariginal marine (evaporites), and terrestrial red bed deposits were formed as the seas fluctuated back and forth over the area. Marine conditions returned in Jurassic time only to retreat at the end of the Jurassic period. A major marine invasion started in early Cretaceous time and continued until the start of the Laramide Revolution and the uplift of the Bighorn Mountains near the end of the Cretaceous period. The Tertiary period was a period of repeated uplift, accompanied by folding, thrusting, and high angle faulting, and the deposition of both thick terrestrial sediments in intermountain basins and potential host rocks for the migration and deposition of uranium (Damp and Brown, 1982). Volcanism was active in the mid to late Tertiary time, and thick volcanic deposits accumulated locally and volcanic ash was widely distributed. This ash or tuff may have been a source rock of uranium; this uranium may have migrated by groundwater into favorable rock units in the area. The Quaternary period is noted for widespread glaciation in the high parts of the Bighorn Mountains, and the accompanying glacial outwash deposits along the flanks of the mountains. During recent geologic time, stream erosion created the area's topography as it is seen today.

3.0 ENERGY AND MINERAL RESOURCES

3.1 General

There are few favorable areas for the occurrence or potential occurrence of GEM resources in either the Gardner Mountain WSA or the North Powder River WSA. Even those areas with favorable geologic environments are rated low on the classification and level of confidence scales. There are uranium occurrences in the Gardner Mountain GRA to the east of the two WSAs, in the Frontier, Cloverly, Morrison, Sundance, Tensleep and Amsden Formations.

Figure 3.1, "Mineral Occurrence Map," illustrates the locations of any known past and present mines, or occurrences of mineral deposits and GEM resources within the Gardner Mountain GRA. Information for this figure came from the USGS' Computerized Resource Information Bank (CRIB), and the USBM's Minerals Availability Information System (MILS).

3.2 Potential Resources

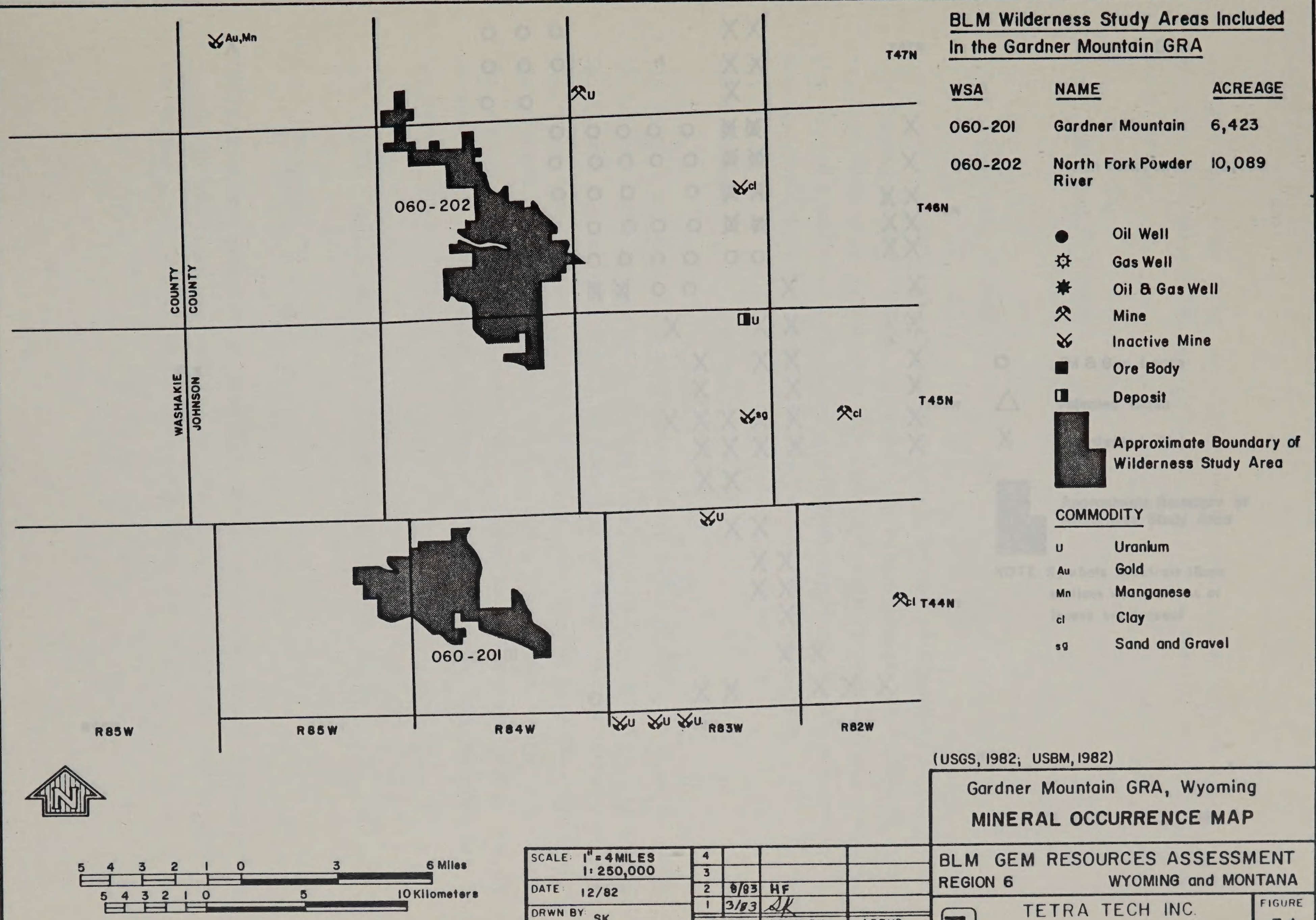
The uranium occurrences in the Tensleep and Amsden Formations mentioned in Section 3.1 are identified as a prospect or mine in the Arminto Quadrangle, Wyoming (Damp and Brown, 1982). Damp and Brown identify the prospect or mine with the comment that production is unknown. Damp and Brown describe the other uranium occurrences as minor prospects or mineral occurrences. The exposures of the Madison Limestone in the study area may be considered nonmetallic mineral occurrences (Love et al., 1978).

3.3 Land Status

The Gardner Mountain GRA contains unpatented claims and oil and gas leases. The unpatented claims were most likely staked for uranium or bentonite. Figure 3.2, "Claim and Lease Map," illustrates the locations of any oil and gas leases, patented claims, and unpatented claims in the Gardner Mountain GRA. As Figure 3.2 illustrates, no claims or leases are within the boundaries of the WSAs.

3.4 Deposit Types

The favorable geologic environments for uranium deposits in the Gardner Mountain GRA are basically secondary deposition in sedimentary rocks. In the Madison and Amsden Formations, solution features (karst topography) in the Madison, which later filled with sandstone blocks of the Amsden, are favorable environments for uranium deposition. In the Tensleep Formation, the Tensleep sandstone, where it is fractured along the crest of the Gardner Mountain anticline, was exposed to uranium-rich groundwater. The Cloverly, Morrison, Sundance, Chugwater, and Tensleep Formations are favorable for sandstone type



BLM Wilderness Study Areas Included In the Gardner Mountain GRA

WSA	NAME	ACREAGE
060-201	Gardner Mountain	6,423
060-202	North Fork Powder River	10,089

(USGS, 1982; USBM, 1982)

Gardner Mountain GRA, Wyoming

MINERAL OCCURRENCE MAP

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FIGURE 3.1

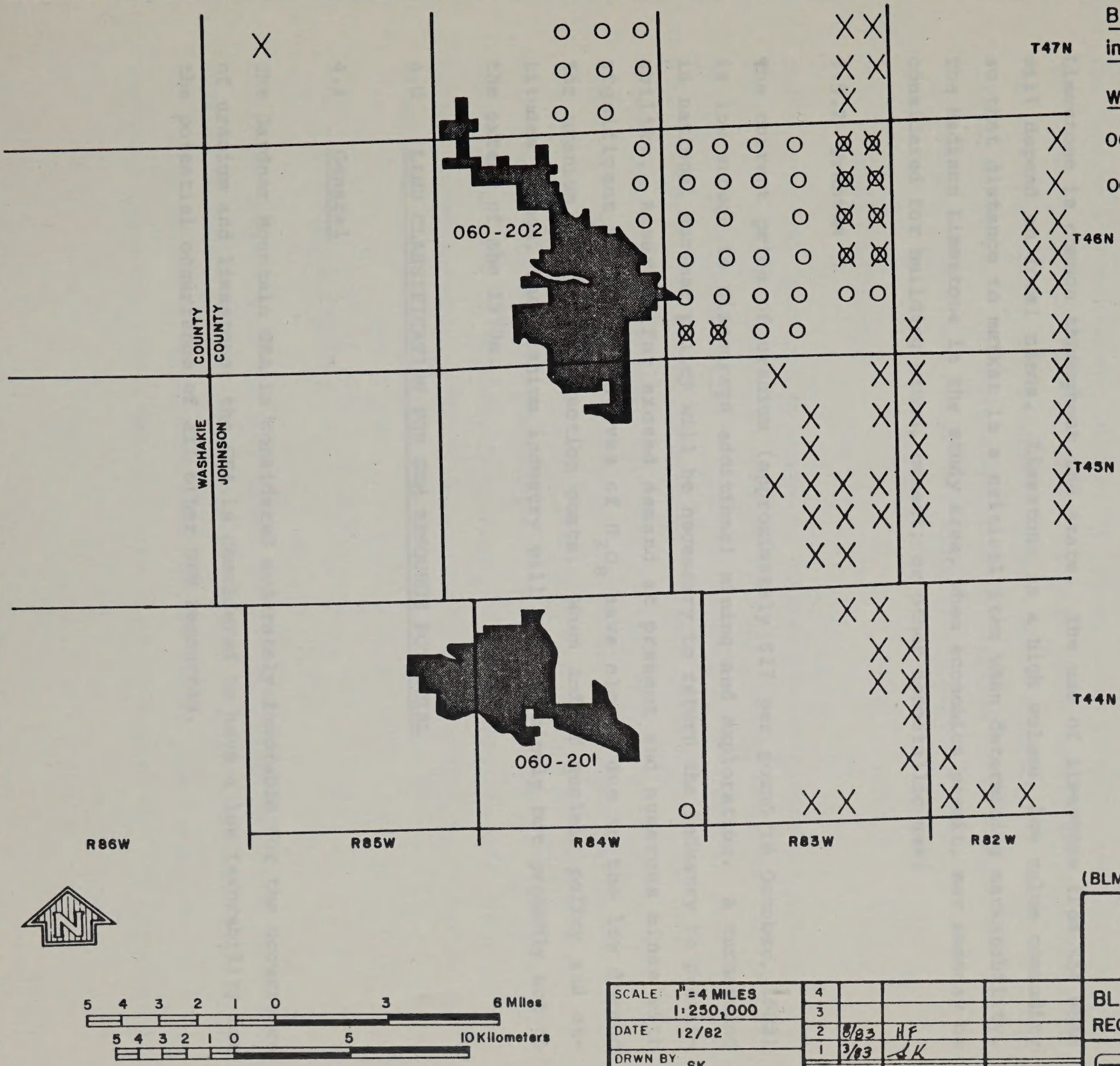
SCALE: 1" = 4 MILES 1:250,000
DATE: 12/82
DRWN BY: SK
APRVD: WL

	DATE	DRWN BY	APRVD
4			
3			
2	8/83	HF	
1	3/83	SK	

REVISIONS

BLM Wilderness Study Areas Included in the Gardner Mountain GRA

WSA	NAME	ACREAGE
060-201	Gardner Mountain	6,423
060-202	North Fork Powder River	10,089



○ Oil & Gas Lease

△ Patented Claim

X Unpatented Claim

▇ Approximate Boundary of Wilderness Study Area

NOTE: Symbols illustrate those sections where claims or leases are present

(BLM, 1982)

SCALE: 1" = 4 MILES 1:250,000	4				
DATE 12/82	3				
DRWN BY SK	2	8/83	HF		
APRVD WL	1	3/83	SK		
		DATE	DRWN BY	APRVD	
	REVISIONS				

Gardner Mountain GRA, Wyoming

CLAIM and LEASE MAP

BLM GEM RESOURCES ASSESSMENT

REGION 6 WYOMING and MONTANA

TETRA TECH INC.
PASADENA, CALIFORNIA

FIGURE 3.2

and fractured rock type deposits because they contain excellent primary porosity, transmissivity, reducing agents, and an uranium source (Damp and Brown, 1982).

3.5 Resource Economics

3.5.1 Industrial Minerals

Limestone is common throughout the state. The use of limestone from the WSAs will depend on local needs. Limestone is a high volume, low value commodity so that distance to market is a critical item when determining marketability. The Madison Limestone in the study area, when economics permit, may someday be considered for building stone, cement, or other nonmetallic use.

3.5.2 Uranium

The current price of uranium (approximately $17 per pound in October, 1982) is low enough to discourage additional mining and exploration. A turnaround in national nuclear policy will be necessary to return the industry to profitability. Reserves far exceed demand at present and numerous mines with significant measured reserves of U_3O_8 have closed due to the low demand for uranium and high production costs. When and if nuclear policy and attitudes change, the uranium industry will recover slowly but probably not to the extent of the 1970s.

4.0 LAND CLASSIFICATION FOR GEM RESOURCE POTENTIAL

4.1 General

The Gardner Mountain GRA is considered moderately favorable for the occurrence of uranium and limestone; the GRA is considered to have a low favorability for the potential occurrence of all other GEM resources.

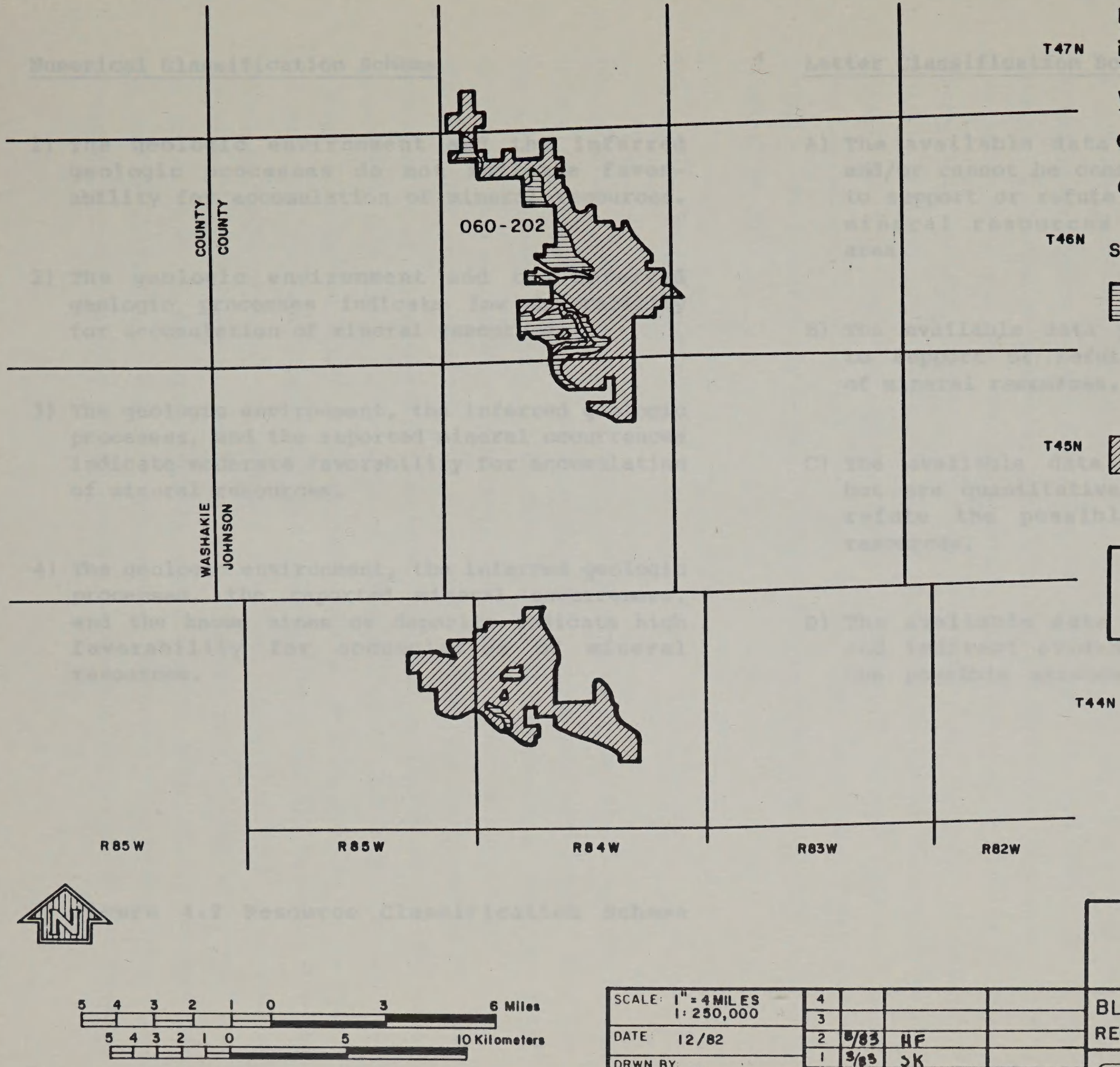
In order to better evaluate the occurrence or potential occurrence of resources in the GRA, a 2-part resource classification scheme has been adopted as requested by contract. Each resource or potential resource within the GRA will receive an alpha-numeric classification. The number designation will range from 1 to 4, and will indicate the favorability of the geologic environment, geologic processes, and mineral occurrences for the presence of a particular resource or group of resources. The letter designation will range from A to D, and will indicate the level of confidence to be associated with the numerical designation. Figure 4.1, "Land Classification Map," illustrates the areas of potential GEM resources with their assigned classifications for the WSAs within the Gardner Mountain GRA. Figure 4.2, "Resource Classification Scheme," provides a detailed description of the number and letter designations used in the resource classification scheme.

4.2 Metallic Minerals

There is a low favorability based on direct but quantitatively minimal evidence for the potential occurrence of metallic minerals in the Gardner Mountain WSA (classified 2C): this classification is based in part upon an examination of the WSA's sedimentary geologic environment, available source rocks, lack of host rocks, and transportation medium for metallic minerals. Similiarly, the sedimentary geologic environment, available source rocks, and transportation medium for metallic resources are not present in the North Fork Powder River WSA for the concentration of metals. Therefore, the North Fork Powder River WSA is considered to have a low favorability for the potential occurrence of metallic minerals (classified 2C); this classification is based upon direct but quantitatively minimal evidence.

4.3 Industrial Minerals

Both the Gardner Mountain and North Fork Powder River WSAs are considered moderately favorable for the potential occurrence of limestone (classified 3C): this potential exists in those areas of the WSAs where the Madison Limestone crops out. Both WSAs are also considered to have a low favorability



BLM Wilderness Study Areas Included in the Gardner Mountain GRA

WSA	NAME	ACREAGE
060-201	Gardner Mountain	6,423
060-202	North Fork Powder River	10,089

SYMBOL	GEM RESOURCE	CLASSIFICATION
▤	Uranium Metallics Oil & Gas Geothermal Limestone Other GEM Resources	3C 2C 2C 2C 3C 2C
▨	Uranium Metallics Oil & Gas Geothermal Other GEM Resources	3C 2C 2C 2C 2C
☐	Approximate Boundary of Wilderness Study Area	

Gardner Mountain GRA, Wyoming

LAND CLASSIFICATION MAP

BLM GEM RESOURCES ASSESSMENT
REGION 6 WYOMING and MONTANA

SCALE: 1" = 4 MILES
1:250,000

DATE: 12/82

DRWN BY: SK

APRVD: WL

	DATE	DRWN BY	APRVD
4			
3			
2	8/83	HF	
1	3/83	SK	

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FIGURE 4.1

Numerical Classification Scheme

1) The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2) The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.

3) The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.

4) The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Letter Classification Scheme (Level of Confidence)

A) The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B) The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C) The available data provide direct evidence, but are quantitatively minimal to support or refute the possible existence of mineral resources.

D) The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Figure 4.2 Resource Classification Scheme

based on direct but quantitatively minimal evidence for the potential occurrence of nonmetallic mineral resources (see Section 4.6 below) (Love et al., 1978).

4.4 Uranium and Thorium

Uranium occurrences have been identified in the Gardner Mountain GRA, just to the east of the WSAs. The geologic environment of these occurrences, the primary and secondary porosity in sandstone, and the presence of uranium bearing groundwaters in the past, can be projected into the WSAs. For these reasons, the formations bearing potential uranium resources have been classified as follows for the Gardner Mountain and North Fork Powder River WSAs: Precambrian, Madison, Amsden, Tensleep, Chugwater, and Sundance Formations - moderate favorability based on direct but quantitatively minimal evidence (classified 3C) (Damp and Brown, 1982). Potential thorium resources (Precambrian calcsilicate veins) for the entire area have been classified as having a low favorability based on direct but quantitatively minimal evidence (classified 2C).

4.5 Oil, Gas, and Geothermal

The necessary temperature gradients and groundwater conditions are not appropriate for geothermal resources in this GRA; therefore, the Gardner Mountain GRA is considered to have a low favorability for geothermal resources based on direct, but quantitatively minimal evidence (classified 2C) (Alpha, 1983). The geologic environment in the area would ordinarily be favorable for the accumulation of hydrocarbons; however, the close proximity of the favorable hydrocarbon formations to outcrops on steeply dipping dip slopes in the area reduces this favorability. The Gardner Mountain WSA is considered to have a low favorability based on direct but quantitatively minimal evidence for the potential occurrence of oil and gas resources (classified 2C). Because of the great depth to sufficient heat in the North Fork Powder River WSA, the the North Fork Powder River WSA is considered to have a low favorability for the potential occurrence of geothermal resources (classified 2C). The potential for oil and gas in the region is severely curtailed by the presence

of outcrops and steep dip slopes. For this reason, the North Fork Powder River WSA is considered to have a low favorability for the potential occurrence of oil and gas resources (classified 2C).

4.6 Other GEM Resources

There exists quatitatively minimal direct evidence to support a low favorability classification for the potential occurrence of other GEM resources in the WSA (classified 2C). This classification is also based in part on the geologic environment and inferred geologic processes that have been identified within the WSA.

5.0 RECOMMENDATIONS FOR FUTURE WORK

5.1 Work Recommended to Complete Data Base

A number of investigations could be implemented to generate additional data to supplement the conclusions of this Phase I report for the Gardner Mountain GRA. Photogeological mapping and a field check at large scale (1:24,000) should be conducted, noting fracture patterns and joints with an emphasis on intersecting linears. Also, an identification of paleokarst on Madison Formations should be conducted to determine uranium favorability. Finally, an evaluation should be made of the upper favorable sandstone above the Madison Formation for uranium favorability characteristics.

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